NATURAL RESOURCES CONSERVATION SERVICE
CONSERVATION PRACTICE STANDARD

GRADE STABILIZATION STRUCTURE

(No.)
CODE 410

DEFINITION

A structure used to control the grade and head cutting in natural or artificial channels.

SCOPE

This standard applies to all types of grade stabilization structures, including a combination of earth embankments and mechanical spillways and full-flow or detention-type structures. This standard also applies to channel side-inlet structures installed to lower the water from a field elevation, a surface drain, or a waterway to a deeper outlet channel. It does not apply to structures designed to control the rate of flow or to regulate the water level in channels (587).

PURPOSE

To stabilize the grade and control erosion in natural or artificial channels, to prevent the formation or advance of gullies, and to enhance environmental quality and reduce pollution hazards.

CONDITIONS WHERE PRACTICE APPLIES

In areas where the concentration and flow velocity of water require structures to stabilize the grade in channels or to control gully erosion. Special attention shall be given to maintaining or improving habitat for fish and wildlife where applicable.

For embankment dams where:

1. Failure of the dam will not result in loss of life; in damage to homes, commercial or industrial buildings, main highways, or railroads; or in interruption of the use or service of public utilities.

2. The product of the storage times the effective height of the dam is less than 3,000. Storage is the volume, in acre-feet, in the reservoir below the elevation of the crest of the auxiliary spillway. The effective height of the dam is the difference in elevation, in feet, between the auxiliary spillway crest and the lowest point in the cross section taken along the centerline of the dam. If there is no auxiliary spillway, the top of the dam is the upper limit.

3. The effective height of the dam is 35 ft or less, and the dam is a low hazard potential (formerly NRCS class “a”).

4. The dam does not exceed limits for class III, small or intermediate, as defined by Illinois Department of Natural Resources, Office of Water Resources. (reference: IDNR Rules & Regulations for construction and maintenance of dams.)

5. Landowner, or other responsible party, has secured necessary permits, if required, for design and construction from IDNR, OWR. Table 1 lists class III dams by dam height and storage and whether or not a permit is required.

TABLE 1 - REQUIREMENT FOR IDNR PERMIT CLASS III DAMS.

Dam Ht* (ft)	Storage to top of Dam (ac-ft.)	Permit Required
0 - 6	All	No
6 - 25	< 50	No
6 - 25	> 50	Yes
> 25	< 15	No
> 25	> 15	Yes

*Dam height is the difference, in feet, measured from the natural bed of the stream or watercourse at the downstream dam slope or toe of the barrier to the top of the embankment or barrier.

Site conditions. Site conditions shall be such that runoff from the design storm can be safely passed through (1) a natural or constructed auxiliary spillway, (2) a principal spillway, or (3)

a combination of a principal spillway and an auxiliary spillway.

DESIGN CRITERIA

The structure must be designed for stability after installation. The crest of the inlet must be set at an elevation that will stabilize upstream head cutting.

Full flow open structures, island type structures, and side inlet drainage structures will be considered embankment dams if the effective height of earth fill (Berms) exceeds 4 feet.

Full-flow open structures. Drop, chute, and box inlet drop spillways shall be designed according to the principles set forth in the National Engineering Handbook (NEH) Part 650, Engineering Field and other applicable NRCS publications and reports. The minimum capacity shall be that required to pass the peak flow expected from a design storm of the frequency and duration shown in table 2, less any reduction because of detention storage. If site conditions exceed those shown in table 2, the minimum design 24-hour storm frequency is 25 years for the principal spillway and 100 years for the total capacity. Structures must not create unstable conditions upstream or downstream. Provisions must be made to insure reentry into the outlet channel of bypassed storm flows.

Toe wall drop structures can be used if the vertical drop is 4 ft or less, flows are intermittent, downstream grades are stable, and tail water depth at design flow is equal to or greater than one-third of the height of the overfall.

Concrete Block or Rock RipRap Chute Spillway structures can be used if the flows are intermittent, downstream grades are stable, and tail water depth at design flow is equal to or greater than the entrance flow depth for the structure.

The ratio of the capacity of **drop box inlets** to road culverts shall be as required by the responsible road authority or as specified in table 4, less any reduction because of detention storage, whichever is greater. The drop box capacity (attached to a new or existing culvert) must equal or exceed the culvert capacity at design flow.

The dimensions of the box shall be sufficient to prevent submergence of the existing culvert headwall at minimum design capacity unless the headwall is raised and designed to act as an anti-vortex device. If the culvert wing walls are flared out from the headwall so as to cause restriction of weir flow into the box, they shall be removed to the elevation of the inlet or the box dimensions increased to compensate for the restriction.

Island-type structures. If the mechanical spillway is designed as an island-type structure, its minimum capacity shall equal the capacity of the downstream channel. For channels with very small drainage areas, the mechanical spillway should carry at least the 2-year, 24-hour storm or the design drainage curve runoff.

The minimum auxiliary spillway capacity shall be that required to pass the peak flow expected from a design storm of the frequency and duration shown in table 2 for total capacity without overtopping the headwall extensions of the mechanical spillway. Provision must be made for safe reentry into the outlet channel of bypassed flow as necessary.

Side-inlet drainage structures. The design criteria for minimum capacity of open-weir or pipe structures used to lower surface water from field elevations or lateral channels into deeper open channels are shown in table 3. The minimum principal spillway capacity shall equal the design drainage curve runoff for all conditions. If site condition values exceed those shown in table 3, the 50-year frequency storm shall be used for minimum design of total capacity.

Table 2. - Design criteria for establishing minimum capacity of full-flow open structures

Maximum Drainage Area	Vertical Drop	Frequency of minimum design, 24-hour duration storm. Principal Spillway Capacity	Total Capacity
Acres	ft	yr	yr
450	5 or less	5	10
900	10 or less	10	25

Table 3. - Design criteria for establishing minimum capacity of side-inlet, open weir, or pipe-drop drainage structures.

Maximum Drainage Area	Vertical Drop	Frequency of minimum design, 24-hour duration storm. Principal Spillway Capacity	Total Capacity
Acres	ft	yr	yr
450	5 or less	----	10
450	5 to 10	5	10
900	5 or less	5	25
900	5 to 10	10	25

Table 4. Design Capacity For Box Inlets to Culverts

Culvert Capacity	Minimum Design Capacity
Less than Q_{50}	1.25 culvert capacity
Greater than Q_{50} but Less than 1.50 Q_{50}	1.25 Q_{50} or culvert capacity (whichever is greater)
Greater than Q_{50}	Culvert capacity not to exceed 1.5 Q_{50}

DESIGN CRITERIA FOR EMBANKMENT DAMS/SPILLWAYS

Embankment dams. Low Hazard Potential (formerly NRCS Class "a") dams that have a product of storage times the effective height of the dam of 3,000 or more, those more than 35 ft in effective height, and all significant hazard potential (formerly NRCS class "b") and high hazard potential (formerly NRCS class "c") dams shall meet or exceed the requirements specified in Technical Release No. 60 (TR-60 - Earth Dams and Reservoirs).
The effective height of the dam is the difference in elevation, in feet, between the auxiliary spillway crest and the lowest point in the cross section along the centerline of the dam. If there is no auxiliary spillway, the top of the dam is the upper limit.

Geological Investigations. Pits, borings, review of existing data or other suitable means of investigation shall be conducted to characterize materials within the embankment foundations, auxiliary spillway and borrow areas. Soil materials shall be classified using the Unified soil classification System. A complete analysis of foundation and earth fill materials shall be made when, in the opinion of the engineer, such analysis is needed.

Foundation cutoff. A cutoff of relatively impervious material shall be provided under the dam if necessary to reduce seepage through the foundation. The cutoff shall be located at or upstream from the centerline of the dam. It shall extend up the abutments as required and be deep enough to extend into a relatively impervious layer or provide for a stable dam when combined with seepage control. The cutoff trench shall have a bottom width adequate to accommodate the equipment used for excavation, backfill, and compaction operations. Side slopes shall not be steeper than one horizontal to one vertical.

Foundation/Embankment Seepage Control. Seepage control shall be provided in all embankments over 25 feet high. For embankments less than 25 feet high, seepage control is to be included if (1) pervious layers are not intercepted by the cutoff, (2) seepage could create swamping downstream, (3) such control is needed to insure a stable embankment, or (4) special problems require drainage for a stable dam. Seepage may be controlled by (1) foundation, abutment, or embankment drains; (2) reservoir blanketing; or (3) a combination of these measures.

Earth embankment. The minimum top width for a dam is shown in table 5. If the embankment top is to be used as a public road, the minimum width shall be 16 ft for one-way traffic and 26 ft for two-way traffic. Guardrails or other safety measures shall be used where necessary and shall meet the requirements of the responsible road authority.

Table 5.- Minimum top width for dams

Total height of embankment	Top width
Ft	Ft
10 or less	6
10 - 15	8
15 - 20	10
20 - 25	12
25 - 35	14
35 or more	15

* Total height of embankment is the difference in feet from the low point along the centerline of dam to the constructed top of dam.

Side Slopes The combined upstream and downstream side slopes of the settled embankments shall not be less than five horizontal to one vertical, and neither slope shall be steeper than two horizontal to one vertical. All slopes must be designed to be stable, even if flatter side slopes are required.

Slope Protection. If needed to protect the slopes of the dam from erosion, special measures, such as berms, rock riprap, sand-gravel, soil cement, or special vegetation, shall be provided (Technical Releases 56 and 69 contain design guidance).

Freeboard. The minimum elevation of the top of the settled embankment shall be 1 ft above the water surface in the reservoir with the auxiliary spillway flowing at design depth. The minimum difference in elevation between the crest of the auxiliary spillway and the settled top of the dam shall be 2 ft for all dams having more than a 20-acre drainage area or more than 20 ft in effective height.

Settlement. The design height of the dam shall be increased by the amount needed to insure that after settlement the height of the dam equals or exceeds the design height.

This increase shall not be less than 5 percent of the height of the embankment, except where detailed soil testing and laboratory analyses show that a lesser amount is adequate. *The height shall be increased by 10% when fill material is pushed up and compacted by a bulldozer.*

Principal spillway. A pipe conduit, with needed appurtenances, shall be placed under or through the dam, except where rock, concrete, or other types of lined spillways are used, or where a vegetated or earth spillway can safely handle the rate and duration of flow.

For dams having a drainage area of 20 acres or less, the principal spillway crest elevation shall not be less than 0.5 ft below the auxiliary spillway crest elevation. For dams with a drainage area over 20 acres, this difference shall not be less than 1.0 feet.

When design discharge of the principal spillway is considered in calculating peak outflow through the auxiliary spillway, the crest elevation of the inlet shall be such that full flow will be generated in the conduit before there is discharge through the auxiliary spillway.

Pipe conduits designed for pressure flow must have adequate anti-vortex devices. The inlets and outlets shall be designed to function satisfactorily for the full range of flow and hydraulic head anticipated.

The capacity of the pipe conduit shall be adequate to discharge long-duration, continuous, or frequent flows without flow through the auxiliary spillways. The diameter of the pipe shall not be less than 4 in. If the pipe conduit diameter is 10 in or greater, its design discharge may be considered when calculating the peak outflow rate through the auxiliary spillway.

The minimum capacity for pipe conduits shall be adequate to discharge the runoff from the frequency storm in Table 6

Table 6. - Design criteria for establishing minimum capacity of spillways for dams with storage capacity of less than 50 acre-feet and overall dam height less than 35 feet.

Maximum Drainage Area	Effective Height of dam	Frequency of minimum design 24-hour duration storm	
		Principal Spillway	Total
Acres	ft	yr	yr
20	0 - 20	5	10
20	21 - 35	10	25
>20	0 - 20	10	25
>20	21 - 35	10	50

If the effective height of the dam is less than 20 ft and the auxiliary spillway has a stable grade throughout its length with no overfalls and has good vegetation along its reentry into the downstream channel, the principal spillway capacity may be reduced but can be no less than 80 percent of the 2-year frequency, 24-hour duration storm.

Grade stabilization structures with a settled fill height of less than 15 ft and 10-year frequency, 24-hour storm runoff less than 10 acre-ft, shall be designed to control the 10-year frequency storm without overtopping. The mechanical spillway, regardless of size, may be considered in design and an auxiliary spillway is not required if the combination of storage and mechanical spillway discharge will handle the design storm. The embankment can be designed to meet the requirements for water and sediment control basins (638).

Pipe Conduit Materials. Pipe conduits shall be ductile iron, welded steel, corrugated steel, corrugated aluminum, reinforced concrete (pre-cast or site cast), or plastic. Pipe conduits through dams of less than 20 feet total height may also be cast iron or un-reinforced concrete.

Pipe conduits shall be designed and installed to withstand all anticipated external and internal loads without yielding, buckling, or cracking. Flexible pipe shall be designed for a maximum deflection of 5 percent. The modulus of elasticity for plastic pipe shall be assumed as one-third of the amount designated by the compound cell classification to account for long term reduction in modulus of elasticity values for the pipe. The minimum thickness of flexible pipe shall be SDR 26, Schedule 40, Class 100, or 16 gage as appropriate for the particular pipe material. Rigid pipe shall be designed for positive projecting conditions. Connections of flexible pipe to rigid pipe or other structures shall be designed to accommodate differential movements and stress concentrations.
All pipe conduits shall be designed and installed to be water tight by means of couplings, gaskets, caulking, waterstops, or welding. Joints shall be designed to remain watertight under all internal and external loading including pipe elongation due to foundation settlement.
All steel pipe and couplings shall have protective coatings in areas that have traditionally experienced pipe corrosion, or in embankments with saturated soil resistivity less than 4000 ohms-cm or soil pH less than 5. Protective coatings shall be asphalt, polymer over galvanizing, or coal tar enamel as appropriate for the pipe type. Plastic pipe that will be exposed to direct sunlight shall be ultraviolet-resistant and protected with a coating or shielding, or provisions provided for replacement as necessary.
Pipe conduits shall have a concrete cradle or bedding if needed to provide improved support for the pipe to reduce or limit structural loading on pipe to allowable levels.
Cantilever outlet sections, if used, shall be designed to withstand the cantilever load.
Pipe supports shall be provided when needed.
Other suitable devices such as a Saint Anthony Falls stilling basin or an impact basin may be used to provide a safe outlet.
New reject or high quality used steel pipe may be used for principal spillway conduits under the following conditions:

(1) Structure is Job Class III or less.
(2) Pipe is of high quality and free of excessive rust and pitting.
(3) Pipe wall thickness is .312 inch, or greater.

Corrugated plastic tubing/pipe with smooth interior may be used. The procedure for qualifying corrugated plastic pipe with smooth interior for installation in fills is set forth in Illinois Bulletin 210-2-7, April 1992.

The requirements listed in tables 7, 8, 8A, and 9 are to be followed for polyvinyl chloride (PVC), steel, and aluminum pipe.

Table 7.- Acceptable PVC pipe for use in earth dams[1]

Nominal pipe size	Schedule for standard dimension ratio (SDR)	Maximum depth of fill over pipe
in		*ft*
4 or less	Schedule 40	15
	Schedule 80	20
	SDR 26	10
6,8,10,12	Schedule 40	10
	Schedule 80	15
	SDR 26	10

[1]Polyvinyl chloride pipe, PVC 1120 or PVC 1220, conforming to ATSM-D-1785 or ATSM-D-2241.

Table 8.- Minimum gage for corrugated metal pipe [2-2/3-in x ½-in corrugations][1]

Fill Height (ft)	Minimum gauge for steel pipe with diameter (in) of ——					
	21 and less	24	30	36	42	48
1 - 15	16	16	16	14	12	10
15 - 20	16	16	16	14	12	10
20 - 25	16	16	14	12	10	10

Fill Height (ft)	Minimum thickness (in) of aluminum pipe[2] with diameter (in) of ——			
	21 and less	24	30	36
1 - 15	0.06	0.06	0.075	0.075
15 - 20	0.06	0.075	0.105	0.105
20 - 25	0.06	0.105	0.105	----[3]

[1] Pipe with 6-, 8-, and 10-in diameters has 1-1/2 in x ¼-in corrugations.

[2] Riveted or helical fabrication.

[3] Not permitted.

Table 8A. Minimum Gauges – Corrugated Steel Pipe – 3" by 1" Corrugations

Pipe Diameter Diameter (Inches)	Fill Height Above Pipe (Feet)		
	1 – 15	15 – 20	20 – 25
36 – 42	16	16	16
48	16	16	14
54	16	16	12
60	16	14	10
66	16	14	8
72	16	14	8
78	14	12	8
84	12	10	*
90	12	8	*
96	10	*	*

* Not Permitted

Table 9. Welded Steel Pipe - Maximum Allowable Fill Over Pipe (Feet)

Pipe Wall Thickness (Inches)	Pipe Diameter (Inches)									
	12	14	16	18	20	22	24	30	36	42
.141	8	5	3	3						
.172	14	9	6	5	3	3				
.188	18	12	8	6	4	3	3			
.219	27	18	12	9	6	5	4			
.250	42	26	18	13	9	7	6	3		
.312			36	26	19	15	12	6	3	3
.375				44	32	25	20	9	6	4
.438						40	33	15	9	6
.500							46	24	14	9

New reject or high quality used steel pipe may be used for principal spillway conduits under the following conditions:

(4) Structure is Job Class III or less.

(5) Pipe is of high quality and free of excessive rust and pitting.

(6) Pipe wall thickness is .312 inch, or greater.

Corrugated plastic tubing/pipe with smooth interior may be used. The procedure for qualifying corrugated plastic pipe with smooth interior for installation in fills is set forth in Illinois Bulletin 210-2-7, April 1992.

Cathodic Protection. Cathodic protection is to be provided for coated welded steel and galvanized corrugated metal pipe where soil and resistivity studies indicate that the pipe needs a protective coating, and where the need and importance of the structure warrant additional protection and longevity. If cathodic protection is not provided for in the original design and installation, electrical continuity in the form of joint-bridging straps should be considered on pipes that have protective coatings. Cathodic protection should be added later if monitoring indicates the need.

Practice standard 430-FF provides criteria for cathodic protection of welded steel pipe.

Seepage Control. Seepage control along a pipe conduit spillway shall be provided if any of the following conditions exist:

1. The effective height of dam is greater than 15 ft.

2. The conduit is of smooth pipe larger than 8 in. in diameter.

3. The conduit is of corrugated pipe larger than 12 in. in diameter.

Seepage along pipes extending through the embankment shall be controlled by use of a drainage diaphragm, unless it is determined that antiseep collars will adequately serve the purpose.

Antiseep collars will be considered adequate for embankments with a relatively impermeable zone up to permanent pool elevation and for all dry dams.

Drainage Diaphragm. The drainage diaphragm shall function both as a filter to eliminate losses of adjacent base soils and a drain for seepage that it intercepts. The drainage diaphragm shall consist of sand meeting the requirements of ASTM C-33 for fine aggregate. If unusual soil conditions exist such that this material may not meet the required filter or capacity requirements, a special design analysis shall be made.

The drainage diaphragm shall be a minimum of 2 ft thick and extend vertically upward and horizontally at least three times the outside pipe diameter, and vertically downward at least 18 in. beneath the conduit invert. The drainage diaphragm shall be located immediately downstream of the cutoff trench, or downstream of the centerline of the dam if the cutoff trench is upstream of the centerline of the dam.

The drainage diaphragm shall be outletted at the embankment downstream toe, preferably using a drain backfill envelope continuously along the pipe to where it exits the embankment. Protecting drain fill from surface erosion will be necessary.

Antiseep Collars. When antiseep collars are used in lieu of a drainage diaphragm, they shall have a watertight connection to the pipe. Maximum spacing shall be approximately 14 times the minimum projection of the collar measured perpendicular to the pipe. The minimum spacing shall be 10 feet. Collar material shall be compatible with pipe materials. The antiseep collar(s) shall increase, by at least 15 percent, the seepage path along the pipe.

Trash Guard. To prevent clogging of the conduit, an appropriate trash guard shall be installed at the inlet or riser unless the watershed does not contain trash or debris that could clog the conduit.

Auxiliary Spillways. Auxiliary spillways convey large flood flows safely past earth embankments and have historically been referred to as "Emergency Spillways".

An auxiliary spillway must be provided for each dam, unless the principal spillway is large enough to pass the peak discharge from the routed design hydrograph and the trash that comes to it without overtopping the dam. The following are minimum criteria for acceptable use of a closed conduit principal spillway

without an auxiliary spillway: a conduit with a cross-sectional area of 3 ft^2 or more, an inlet that will not clog, and an elbow designed to facilitate the passage of trash.

The minimum capacity of a natural or constructed auxiliary spillway shall be that required to pass the peak flow expected from a design storm of the frequency and duration shown in table 3, less any reduction creditable to conduit discharge and detention storage.

The auxiliary spillway shall safely pass the peak flow, or the storm runoff shall be routed through the reservoir. The routing shall start either with the water surface at the elevation of the crest of the principal spillway or at the water surface after 10 days' drawdown, of the principal spillway routed storm, whichever is higher. The 10-day drawdown shall be computed from the crest of the auxiliary spillway or from the elevation that would be attained if the entire design storm were impounded, whichever is lower. Auxiliary spillways shall provide for passing the design flow at a safe velocity to a point downstream where the dam will not be endangered.

When the principal spillway is a closed conduit with diameter 10" or larger, and drainage area is less than 250 acres, the required capacity of the auxiliary spillway may be computed by subtracting the peak principal spillway design storm flow from the peak auxiliary spillway design storm inflow, in lieu of any routing procedure. The auxiliary spillway will be designed using procedures found in chapter 11 of the engineering field handbook.

Constructed auxiliary spillways are open channels that usually consist of an inlet channel, a control section, and an exit channel. They shall be trapezoidal and shall be located in undisturbed or compacted earth or in-situ rock. The side slopes shall be stable for the material in which the spillway is to be constructed. For dams having an effective height exceeding 20 ft, the auxiliary spillway shall have a bottom width of not less than 10 ft.

Upstream from the control section, the inlet channel shall be level for the distance needed to protect and maintain the crest elevation of the spillway. The inlet channel may be curved to fit existing topography. The grade of the exit channel of a constructed auxiliary spillway shall fall within the range established by discharge requirements and permissible velocities.

Spillway dikes or shaped exit channels shall be used as needed to insure that spillway flows do not damage the earth embankments. The constructed spillway dike shall have a minimum side slope of 2:1, a minimum top width of 4 ft and a minimum height of 2 ft above the outlet channel grade.

Trash Guard. To prevent clogging of the conduit, an appropriate trash guard shall be installed at the inlet or riser unless the watershed does not contain trash or debris that could clog the conduit.

Cathodic Protection. Cathodic protection is to be provided for coated welded steel and galvanized corrugated metal pipe where soil and resistivity studies indicate that the pipe needs a protective coating, and where the need and importance of the structure warrant additional protection and longevity. If cathodic protection is not provided for in the original design and installation, electrical continuity in the form of joint-bridging straps should be considered on pipes that have protective coatings. Cathodic protection should be added later if monitoring indicates the need.

Practice standard 430-FF provides criteria for cathodic protection of welded steel pipe.

Landscape resources. In highly visible public areas and those associated with recreation, careful considerations should be given to landscape resources. Landforms, structural materials, water elements, and plant materials should visually and functionally complement their surroundings. Excavated material and cut slopes should be shaped to blend with the natural topography. Shorelines can be shaped and islands created to add visual interest and valuable wildlife habitat. Exposed concrete surfaces may be formed to add texture or finished to reduce reflection and to alter color contrast. Site selection can be used to reduce adverse impacts or create desirable focal points.

General criteria. Earth embankment and auxiliary spillways of structures for which criteria are not provided under the standard or

in TR-60 must be stable for all anticipated conditions. If earth spillways are used, they must be designed to handle the total capacity flow indicated in table 6 without overtopping the dam. The foundation preparation, compaction, top width, and side slopes must ensure a stable dam for anticipated flow conditions. Discharge from the structure shall be sufficient that no crop damage results from flow detention.

The earth embankment pond structures are potentially hazardous and precautions must be taken to prevent serious injury or loss of life. Protective guardrails, warning signs, fences, or lifesaving equipment shall be added as needed.

If the area is used for livestock, the structures, earthfill, vegetated spillways, and other areas should be fenced as necessary to protect the structure. Near urban areas, fencing may be necessary to control access and exclude traffic that may damage the structure or to prevent serious injury or death to trespassers.

Protection. The exposed surfaces of the embankment, earth spillway, borrow area, and other areas disturbed during construction shall be seeded or sodded as necessary to prevent erosion. If climatic conditions preclude the use of vegetation, non-vegetative coverings such as gravel or other mulches may be used.

PLANS AND SPECIFICATIONS

Plans and specifications for installing grade stabilization structures shall be in keeping with this standard and shall describe the requirements for applying the practice to achieve its intended purpose.

Quantity

1. Effects on volumes and rates of runoff, evaporation, deep percolation and ground water recharge.
2. Effects of the structure on soil water and resulting changes in plant growth and transpiration.

Quality

1. Ability of structure to trap sediment and sediment-attached substances carried by runoff.
2. Effect of structure on the susceptibility of downstream stream banks and streambeds to erosion.
3. Effects of the proposed structure on the movement of dissolved substances to ground water.
4. Effects on visual quality of downstream water resources.